



Southwest Georgia Interstate Study

Technical Memorandum

Development of Travel Demand Model

1.0 Introduction

Since many vehicles using Interstate highways are making long-distance trips, the geographic coverage and modeling techniques used for the Southwest Georgia Interstate Study (SWGIS) model differ from most urban travel demand modeling applications. To properly model long-distance highway path choices and national freight patterns, the SWGIS model covers the contiguous forty-eight states, rather than only the study area. Additionally, the model extends beyond the traditional four-step travel demand modeling approach, typical in urban areas, to include Trip Table Estimation (TTE) techniques to develop reliable trip tables.

2.0 Review of the Interstate System Plan Model

The initial plan for developing the Southwest Georgia Interstate Plan travel demand model was to refine the State of Georgia Interstate System Plan (ISP) model. When developing the initial plan for the SWGIS modeling approach, the ISP model was still under development and it was anticipated that it would be prudent to refine it for use in the SWGIS. However, after reviewing the ISP model, several important concerns prevented its use: geographic coverage, zonal detail, network connectivity and the use of basic TTE techniques in developing trip tables.

It was anticipated that the geographic coverage of the ISP model would have to be expanded, but since it did not include any geographic areas outside the State of Georgia, it would have to be expanded significantly. County boundaries were used as Traffic Analysis Zones (TAZ) for the ISP. It was anticipated that the ISP zones would need to be divided to create a more defined zone structure within the study area, but county level zones provided limited benefit over defining new zones altogether. Although making geographic coverage and zonal detail refinements would be substantial, these were minor issues regarding refining the ISP model for use in the SWGIS. Highway network connectivity coding problems and basic TTE techniques were a more substantial concern. Since the ISP trip tables were developed with basic TTE techniques, network coding errors caused trip tables to be less reliable. For example, highway links in the ISP network for US-280 south of Columbus were disconnected, which prevented trips traveling between Columbus and Albany from using the primary route between these cities. TTE techniques adjust trip tables to ensure that assigned modeled volumes closely match observed traffic counts, but if no logic controls are placed on the adjustment process, unreasonable results can be produced. Since the ISP model used basic TTE techniques without logic controls, the US-280 network coding error resulted in poor estimates of travel patterns in the area, including an estimated large number of trips traveling to and from very rural areas south of Columbus.



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3.0 Overview of the Southwest Georgia Interstate Study Model

As noted previously, the SWGIS model extends beyond traditional four-step travel demand model techniques to include TTE. TTE methods generally all require a starting trip table that is then adjusted to improve comparisons to observed data. This starting trip table is called a “seed trip table.” Simple assumptions can be used to build seed trip tables, but better results are obtained from TTE procedures when more accurate “seed” trip tables are used. For this reason, considerable efforts were made to develop seed trip tables that produced reasonable travel patterns when compared to observed data, before beginning any TTE work. This approach places fewer burdens on the TTE process to produce reasonable results, and improves the overall reliability of the estimated trip tables. Once reasonable seed trip tables were produced, relatively sophisticated TTE methods were used to develop reliable trip tables for use in the SWGIS.

3.1. Seed Trip Table Development Summary

Traditional four-step travel demand modeling procedures were used to develop initial seed tables for the SWGIS model. The traditional four-step process includes trip generation, trip distribution, mode choice and trip assignment. In most cases, model parameters for each step are based on commonly used national data sources, such as the National Household Travel Survey (NHTS) and the Quick Response Freight Manual II.

Short distance person trips are modeled between study area zones, tract-level zones and county-level zones¹. They are not modeled between regional planning level zones and state-level zones. Short distance commercial vehicle trips are only modeled between study area zones. Long-distance person trips are modeled between all zones in the contiguous forty-eight states. Freight trips by truck are modeled between the contiguous forty-eight states, Canada and Mexico. Table 3.1.1 displays the geographic level that is modeled for each trip type.

Table 3.1.1
Geographic Level Modeled for Trip Types

Trip Type	Zone-Level Modeled					
	Study Area	Tract	County	Regional	State	Can/Mex
Short Distance Person Trips	Yes	Yes	Yes	No	No	No
Short Distance Commercial Vehicles	Yes	No	No	No	No	No
Long Distance Person Trips	Yes	Yes	Yes	Yes	Yes	No
Freight by Truck	Yes	Yes	Yes	Yes	Yes	Yes

¹ See Traffic Analysis Zone Development Documentation for a description of the zone organization scheme.



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Trip generation and trip distribution are performed for all of the trip purposes except freight by truck. Freight by truck trip tables were separately developed from Freight Analysis Framework (FAF) data². Long-distance person trips are converted to long-distance person trips by personal vehicle using simple shares from the NHTS (mode choice). All person trip purposes are converted to highway vehicle trips using auto occupancy rates by purpose. Once daily vehicle trip tables are created for all trip purposes, all of the vehicle trips are assigned to the highway network (Trip Assignment).

3.2. Trip Table Estimation (TTE)

There are many potential approaches to estimating trip tables using observed data, with a wide range of complexity. The approach used to estimate trip tables for the ISP model used a relatively simple approach without logic controls, resulting in unreliable trip tables. To limit such issues, the TTE approach for the SWGIS model adds import logic controls. To understand the importance of these logic controls, it is important to have a general understanding of basic TTE methods.

3.2.1. Basic TTE

Most common TTE applications use observed traffic counts to estimate vehicle trip tables. Another example of a TTE application might use observed transit passengers to estimate a transit person trip table. For the SWGIS model, observed traffic counts were used to refine seed trip tables that were created using traditional travel demand modeling methods. A basic TTE approach determines the highway path between two locations. Then seed trips are assigned to this path. After the trips are assigned, it is then possible to sum the observed traffic counts and assigned trips (where counts are available) to determine if too few or too many trips are traveling between the two locations. If the assigned trips are greater than the observed counts, then the trip table can be adjusted to reduce the trips. If the assigned trips are less than the observed counts, then trip table can be adjusted to increase the trips. When this approach is applied to many different locations, adjustments made for one pair of locations may counteract adjustments made for another pair. To overcome these sorts of competing adjustments, TTE procedures are iteratively applied, with an adjusted table output from one iteration serving as the seed for the next iteration, and the process is repeated until relatively small changes occur between iterations.

To illustrate how a basic TTE procedure can produce erroneous results, consider the situation shown in Figure 3.2.1.1.

² See Truck Trip Table Documentation for details.

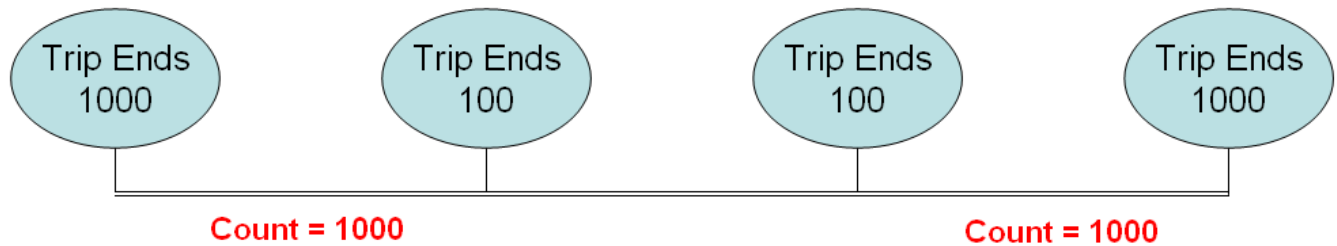


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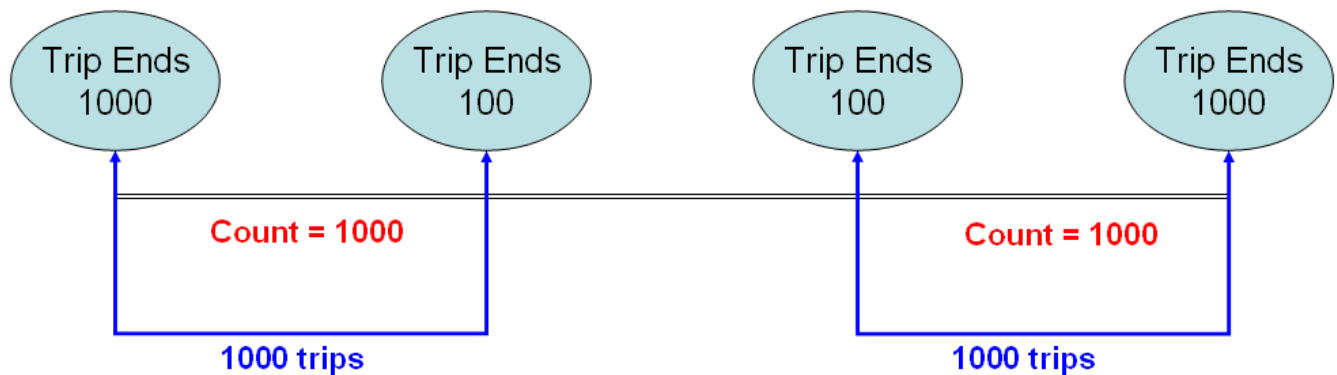
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Figure 3.2.1.1
Trip Table Estimation Example Information



Based on the amount of activity (households, jobs, etc.) in each zone, the two outer zones are expected to have 1000 trip ends and the two inner zones have less activity and are expected to only have 100 trip ends. Two observed traffic counts are available, with each being 1000. Most TTE techniques have a tendency to solve this problem by adding short trips. Figure 3.2.1.2 displays an erroneous solution that illustrates why this often occurs.

Figure 3.2.1.2
Erroneous TTE Solution



An easy way to create a trip table that perfectly matches the traffic counts is to generate 1000 short trips between the adjacent zones on each side of the traffic counts. An important problem with this solution is that ten times too many trips are sent to and from the inner two zones. To minimize this type of problem it is important to add a logical control on the TTE process that attempts to constrain the final estimated trip table close to the expected number of trip ends for each zone (i.e. trip end controls). Figure 3.2.1.3 displays a more reasonable solution to the problem.

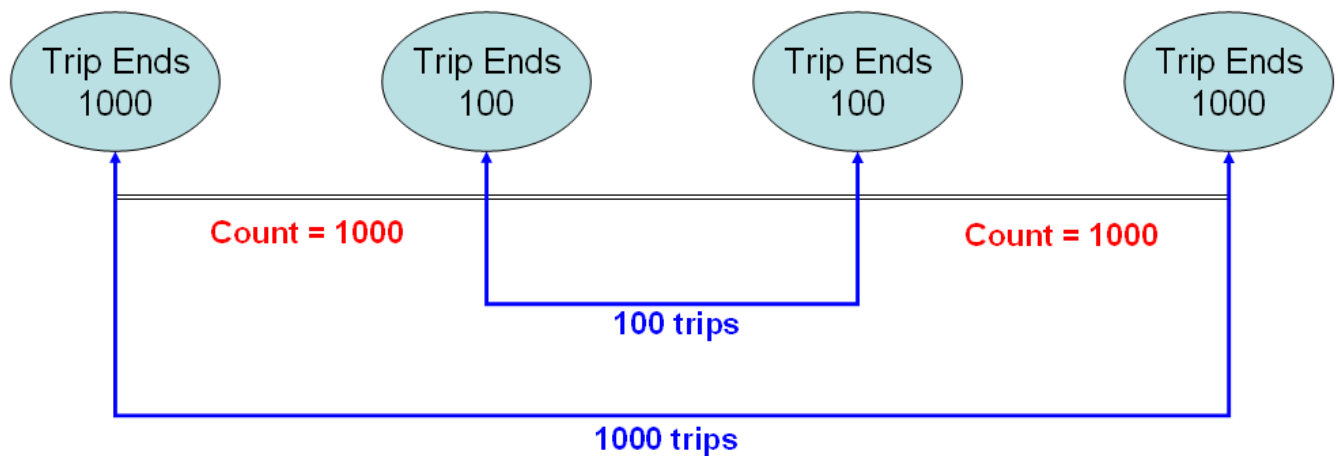


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Figure 3.2.1.3
A More Reasonable TTE Solution



The solution shown in Figure 3.2.1.3 would perfectly match up to the traffic counts and it also matches the expected number of trip ends for each zone, but it illustrates another important logic control. Although more reasonable, the solution shown in Figure 3.2.1.3 is probably not an entirely accurate solution because the most reasonable solution would likely include short, medium and long trips, not just the short and long trips that are shown. To ensure that a reasonable mix of short, medium and long trips is included in the final solution, it is important to include controls on the trip length frequency distribution (i.e. trip length controls). To improve the reasonableness of the trip tables for the SWGIS model, the TTE approach includes controls for both trip ends and trip length frequency.

4.0 Seed Trip Table Development

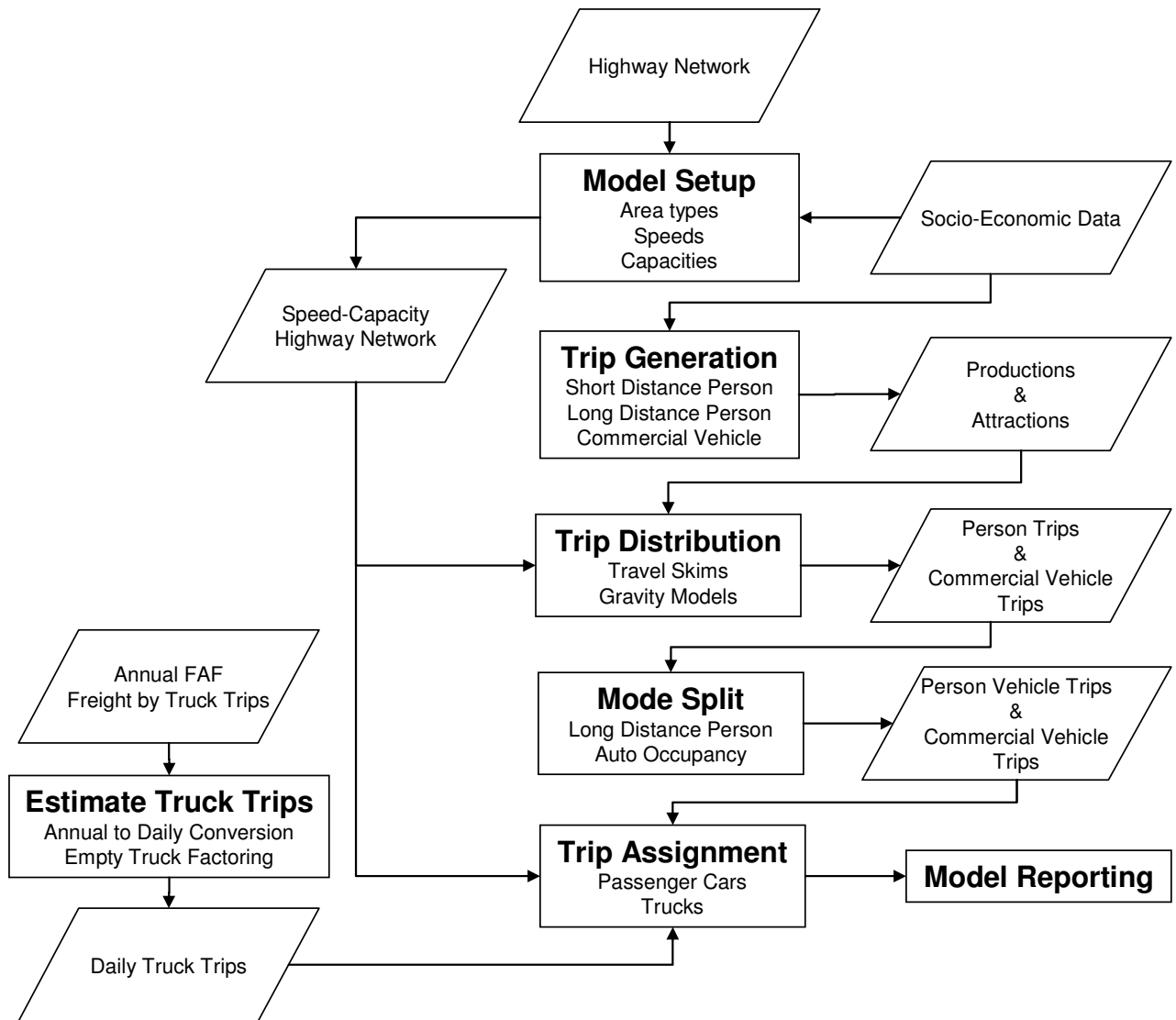
Figure 4.1 displays a flow-chart summarizing the SWGIS model process. Seed trip table development begins with model setup steps to add speeds and capacities to the input highway network which are required for subsequent model steps. Trip generation calculations are applied to estimate trip ends (productions & attractions). Trip distribution calculations are applied to estimate a preliminary set of trip tables. Mode choice calculations are applied to convert total long distance person trips to long-distance person trips made by passenger car. While applying mode choice calculations other person trips are converted to passenger car trips and all trips are converted to origin-destination format.




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	Seed Trip Table Model Flow	
Development of TDM		
Figure 4.1		



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Before trip assignment, separate model steps are applied to convert annual freight trips made by truck to daily truck trips. Once passenger car and truck trip tables are available, the trips are assigned to the highway network using a capacity restrained assignment method. Following highway assignment, model reporting calculations are made to evaluate model results.

4.1. Model Setup

Model setup steps receive the input highway network and socio-economic data to build a highway network that includes speeds and capacities on all links. Link speed and capacity assumptions vary by the level of urbanization around each link, so it is first necessary to estimate the area type for each link in the network. To estimate the area type for each link, TAZ area types are estimated based on population density and then each link is assigned the area type of the closest TAZ to the link. Table 4.1.1 summarizes the area types and population density assumptions that were used. The population density ranges were defined to approximate U.S. Census 2000 Urban Area Definitions³. This was accomplished by manually assigning each TAZ to an area type and then summarizing population densities into percentiles. Range values (rounded to the nearest ten) were then selected that captured a high proportion of zones into their desired area type.

Table 4.1.1
Area Type Assumptions

Area Type	Population per Square Mile
Metropolitan	> 1000
Small Urban	between 150 & 1000
Rural	<= 150

Since area types are based upon population densities, area types automatically adjust to changes in socio-economic data assumptions. If population growth occurs in a rural area, making it more urban, the area type will change reflecting this. And since speeds and capacities vary by area type, they will also adjust to the population growth.

The assumed highway capacities are based on Florida Level of Service Handbook generalized level of service (LOS) tables, which are widely used throughout the United States. These tables are heavily based on the Highway Capacity Manual⁴ while also being easily used in planning applications. Table 4.1.2 displays the assumed per lane capacities.

³ Details and GIS files are available at: <http://www.census.gov/geo/www/ua/uaucbndy.html>

⁴ Highway Capacity Manual (HCM) procedures are the national standard for detailed highway capacity analysis.



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Table 4.1.2
Capacity per Lane (vehicles per day)

Facility Type	Area Type		
	Metropolitan	Small Urban	Rural
Interstate	19125	17275	15750
Freeway / Expressway	19125	17275	15750
Principal Arterial	8450	8150	11150
Minor Arterial	7750	7650	7450
Major Collector	6300	6150	7450
Minor Collector	6300	6150	6050
Local Road	6300	6150	6050
Centroid Connector	0	0	0

Multilane highways generally have higher per lane capacities than single lane highways. To reflect this benefit of multilane highways, capacity adjustment factors are applied to multilane highways. Table 4.1.3 displays the assumed multilane adjustment factors. The factors in Table 4.1.3 were developed to approximate the multilane capacity benefits reflected in the Florida LOS tables.

Table 4.1.3
Multilane Adjustment Factors

Facility Type	Area Type		
	Metropolitan	Small Urban	Rural
Interstate	1.08	1.07	1.04
Freeway / Expressway	1.08	1.07	1.04
Principal Arterial	1.08	1.05	1.31
Minor Arterial	1.05	1.05	1.05
Major Collector	1.05	1.05	1.05
Minor Collector	1.05	1.05	1.05
Local Road	1.05	1.05	1.05
Centroid Connector	1.00	1.00	1.00

Table 4.1.4 displays the assumed free-flow speeds used in the SWGIS model. Free-flow speeds are used to calculate zone-to-zone travel times for use in the trip distribution model and also in the estimation of congested times during traffic assignment.



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Table 4.1.4
Freeflow Speed (miles per hour)

Facility Type	Area Type		
	Metropolitan	Small Urban	Rural
Interstate	65	68	70
Freeway / Expressway	55	60	65
Principal Arterial	45	50	60
Minor Arterial	40	45	55
Major Collector	35	40	45
Minor Collector	30	35	40
Local Road	20	25	30
Centroid Connector	40	40	40

4.2. Trip Generation

The first major travel demand model component is the trip generation model. This model component estimates the total number of person trips that are produced in and attracted to each traffic analysis zone, i.e. this model component estimates the magnitude of the trip making in each traffic analysis zone. The trip generation model estimates the number of productions and attractions in each traffic analysis zone by various trip purposes.

Trips are categorized into trip purposes due to the significant differences in trip characteristics associated with each trip purpose. The SWGIS model uses three commonly used trip purposes for short-distance person trips: Home-Based Work, Home-Based Other and Non-Home Based. Long-distance person trips, commercial vehicles and freight by trucks are modeled as individual trip purposes. To summarize, the following trip purposes are modeled:

- Home-Based Work (HBW) Person Trips
- Home-Based Other (HBO) Person Trips
- Non-Home Based (NHB) Person Trips
- Long-Distance Person Trips
- Short-Distance Commercial Vehicles
- Freight by Truck

Person trip productions are calculated using the trip rates shown in Table 4.2.1, which are based on trip rates observed in the 2001 NHTS.



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Table 4.2.1
Person Trip - Production Trip Rates (trips per HH)

Traffic Analysis Zone Category	Trip Purpose			
	HBW	HBO	NHB	LONG
Study Area	1.7	5.0	3.2	0.070
Tract	1.5	4.5	2.5	0.070
County	1.3	4.0	2.0	0.070
Regional Planning	0.0	0.0	0.0	0.065
State	0.0	0.0	0.0	0.060

Trip attractions for person trip purposes are shown in Tables 4.2.2, where the heading abbreviations represent the following:

HH = Households
TOTEMP = Total Employment
AMC = Agriculture, Mining and Construction Employment
MFG = Manufacturing Employment
WFW = Warehouse, Freight and Wholesale Employment
RET = Retail Employment
SER = Service Employment
SCHOOL = School Enrollment
COLLEGE = College Enrollment

These headings are also used in Table 4.2.3.



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Table 4.2.2
Person Trip - Attraction Trip Rates

Traffic Analysis Zone Category	Trip Generator								
	HH	TOTEMP	AMC	MFG	WFW	RET	SER	SCHOOL	COLLEGE
<u>Home Based Work</u>									
Study Area	-	1.7	-	-	-	-	-	-	-
Tract	-	1.0	-	-	-	-	-	-	-
County	-	1.0	-	-	-	-	-	-	-
Regional Planning State	zero productions zero productions								
<u>Home Based Other</u>									
Study Area	0.7	-	0.05	0.5	0.5	8.0	2.0	1.3	1.1
Tract	0.7	2.6	-	-	-	-	-	-	-
County	0.7	2.6	-	-	-	-	-	-	-
Regional Planning State	zero productions zero productions								
<u>Non-Home Based</u>									
Study Area	0.6	-	0.05	1.0	0.8	6.0	1.5	0.8	1.0
Tract	0.6	1.1	-	-	-	-	-	-	-
County	0.6	1.1	-	-	-	-	-	-	-
Regional Planning State	zero productions zero productions								
<u>Long Distance Trips</u>									
All Zones	set equal to productions								

Freight by truck trips are developed from FAF annual truck trip tables⁵. Annual FAF truck trip tables were converted to daily truck trips using an annual to daily conversion factor of 365. Daily FAF truck trip tables represent trucks carrying freight, but empty trucks can be a significant portion of truck travel. The best available information on empty truck travel is the US Census Bureau's Vehicle Inventory and Use Survey (VIUS). VIUS data provides information on the percent of vehicle miles driven while empty, but it does not provide information on the trip length frequency of empty truck trips. Data that is available indicates that empty truck trips constitute approximately 25% of vehicle-miles traveled. To develop a reasonable estimate of empty truck trips, the following assumptions were made:

- Assume empty trucks represent no more than about 30% of the total truck trips between zones
- Since efficient truckers likely seek opportunities to move freight in both directions of long trips, assume the empty truck probability declines with increases in trip distance
- Assume the empty truck probability becomes effectively zero for trips of 250 miles or greater

⁵ See Truck Trip Table Documentation for details.



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The following binary logit formulation was used to account for empty trucks and it closely represents the aforementioned assumptions:

$$\text{Empty Truck Factor} = 1 + \frac{\exp(-0.04 \times \text{distance})}{(1 + \exp(-0.04 \times \text{distance}))}$$

To account for empty trucks, the FAF daily trucks are multiplied by the empty truck factor.

Initially truck trips were represented solely by those estimated using FAF trip tables. When FAF daily truck trip tables were assigned to the highway network the large-scale travel patterns were reasonable, but study area truck volumes were underrepresented. This is likely due to the large geographic scale of the FAF data relative to the much smaller study area zones. The addition of a short-distance commercial vehicle trip purpose helped to improve the resulting truck volumes in the study area.

Short distance commercial vehicle and truck trip ends were initially based on trip rates shown in Table 4.1 of the Quick Response Freight Manual II. Minor adjustments to trip rates were made during calibration of the SWGIS model resulting in the trip rates shown in Table 4.2.3.

Table 4.2.3
Commercial Vehicle – Production and Attraction Trip Rates

Traffic Analysis Zone Category	Trip Generator								
	HH	TOTEMP	AMC	MFG	WFW	RET	SER	SCHOOL	COLLEGE
Study Area - Productions	0.4	-	1.4	1.2	1.2	1.1	0.5	-	-
Study Area - Attractions	0.4	-	1.4	1.2	1.2	1.1	0.5	-	-
Outside Study Area	zero productions								

These commercial vehicle trip rates are used to estimate the total commercial vehicle and truck activity for zones in the study area. Truck traffic counts collected in the study area represent medium and heavy trucks, generally corresponding to vehicles within groups 4 through 13 in the Federal Highway Administration (FHWA) vehicle classification scheme shown in Figure 4.2.1. Since small commercial vehicles are typically passenger cars, vans and pickup trucks that are used for business purposes, common traffic counting equipment can not distinguish them from other personal vehicles. Subsequent TTE steps adjust the total commercial vehicle and truck demands to represent only medium and heavy trucks.


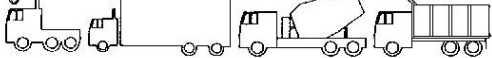
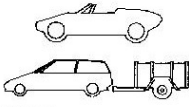
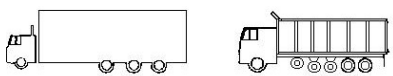
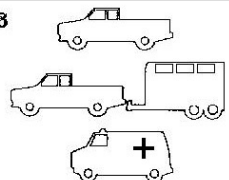
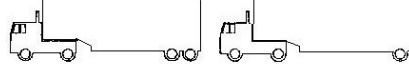
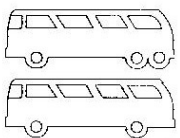
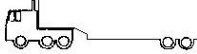
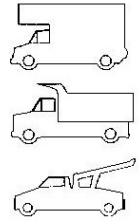
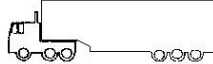
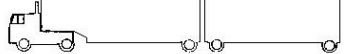
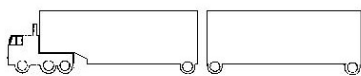



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Figure 4.2.1
FHWA Vehicle Classification Groups⁶

<p>1</p>  <p>MOTORCYCLES</p>	<p>6</p>  <p>THREE AXLE, SINGLE UNIT</p>
<p>2</p>  <p>PASSENGER CARS</p>	<p>7</p>  <p>FOUR OR MORE AXLE, SINGLE UNIT</p>
<p>3</p>  <p>FOUR TIRE, SINGLE UNIT</p>	<p>8</p>  <p>FOUR OR LESS AXLE, SINGLE TRAILER</p>
<p>4</p>  <p>BUSES</p>	<p>9</p>  <p>FIVE-AXLE, SINGLE TRAILER</p>
<p>5</p>  <p>TWO AXLE, SIX TIRE SINGLE UNIT</p>	<p>10</p>  <p>SIX OR MORE AXLE, SINGLE TRAILER</p>
	<p>11</p>  <p>FIVE OR LESS AXLE, MULTI-TRAILER</p>
	<p>12</p>  <p>SIX AXLE, MULTI-TRAILER</p>
	<p>13</p>  <p>SEVEN OR MORE AXLE, MULTI-TRAILER</p>

4.3. Trip Distribution

The purpose of the trip distribution step is to establish the overall trip patterns between traffic analysis zone pairs. It is important to understand that these trip distribution procedures do not select the mode or route that the trips will take. Rather, the distribution model focuses on the linking of trips from origin to destination. The SWGIS model uses a gravity model formulation, which is so named because its logic closely follows the calculation of the force of gravity. Just as the force of gravity is proportional to the mass of two objects; the probability of trips occurring between two zones is proportional to the magnitude of trip productions and attractions estimated for the two

⁶ Source: http://www.dot.state.oh.us/Divisions/Planning/TechServ/Prod_Services/SchemeF/Documents/SchemeF.pdf



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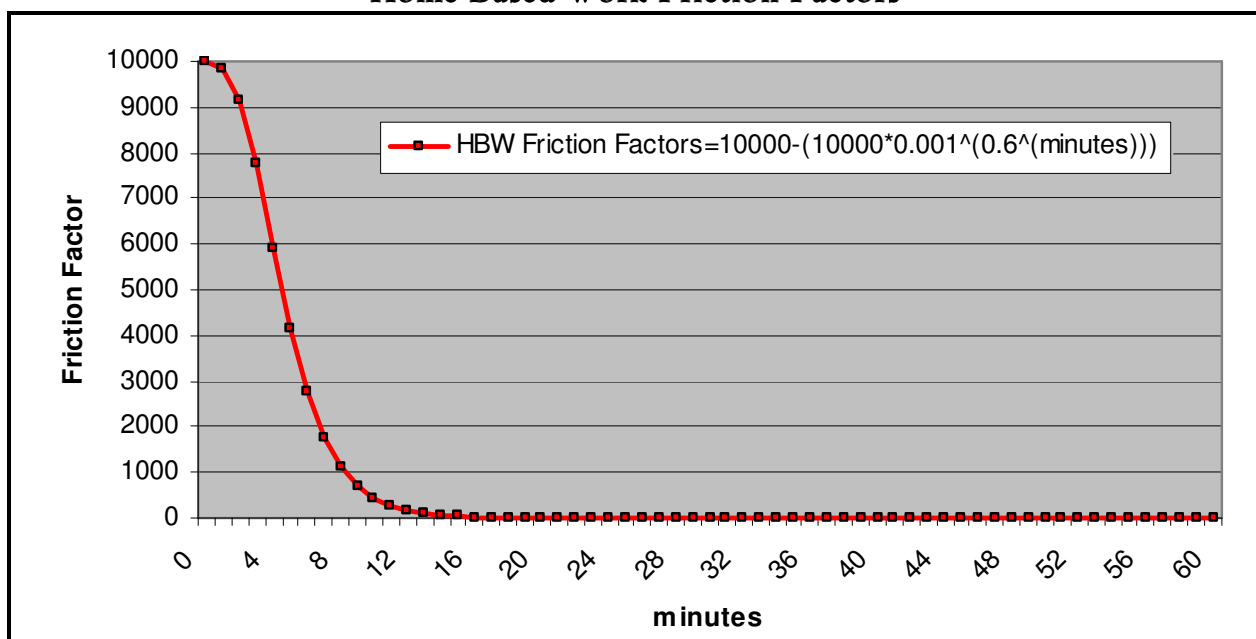
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zones. Smaller trip ends decrease the likelihood of trips and larger trip ends increase the likelihood of trips. Likewise, just as the force of gravity is inversely proportional to the spatial separation between two objects; the probability of trips occurring between two zones is inversely proportional to the spatial separation (or travel time) between the zones. Shorter travel times increase the probability of trips and longer travel times decrease the probability of trips.

The SWGIS model uses the travel time, as is most commonly used in trip distribution models, as the measure of spatial separation. Since the trip probability is inversely proportional to travel time, there has to be a mechanism to represent the declines in trip probability as travel time increases. This is accomplished using friction factors. Friction factors represent the inverse relationship by decreasing in value as travel time increases.

Gravity models are generally calibrated to closely match target average trip lengths and observed trip length frequency distributions. NHTS 2001 data indicates that short-distance person trips typically average between 15 and 20 minutes. Trip length frequency distributions are not available in the NHTS and they can vary significantly from city to city. For this reason, distribution model calibration for short-distance person trips was limited to adjusting friction factor curves to produce 15 to 20 minute average trip lengths. Figures 4.2.1, 4.2.2 and 4.2.3 display the final SWGIS model friction factor curves for short-distance person trips.

Figure 4.2.1
Home Based Work Friction Factors





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Figure 4.2.2
Home Based Other – Friction Factors

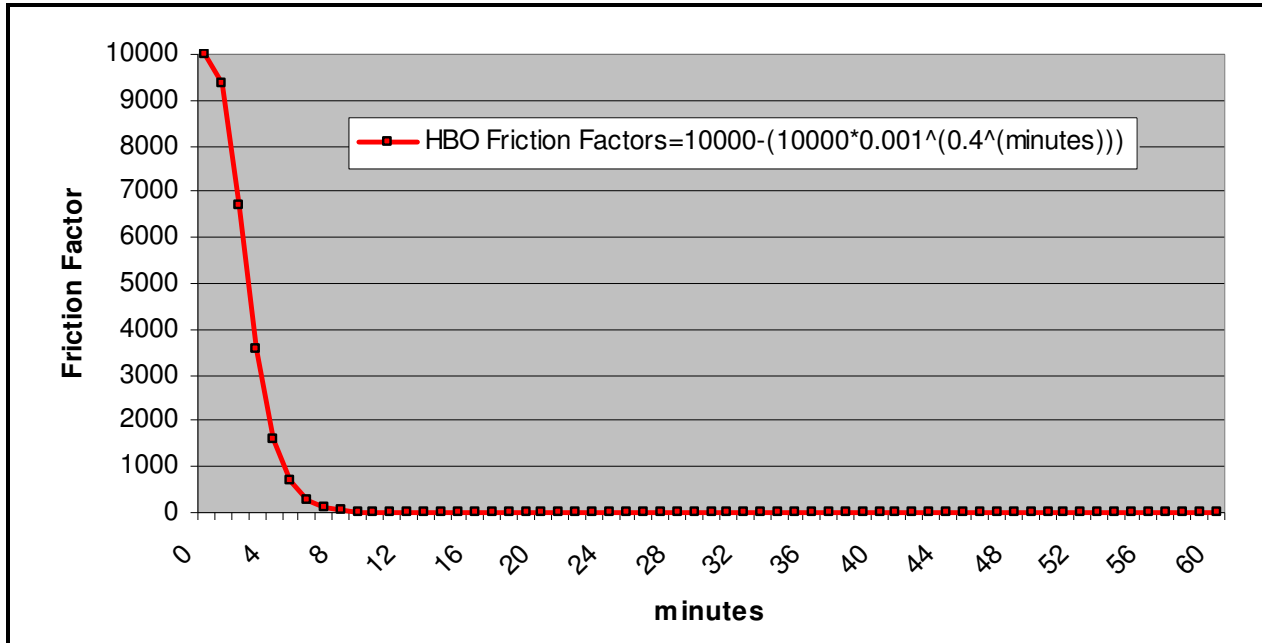
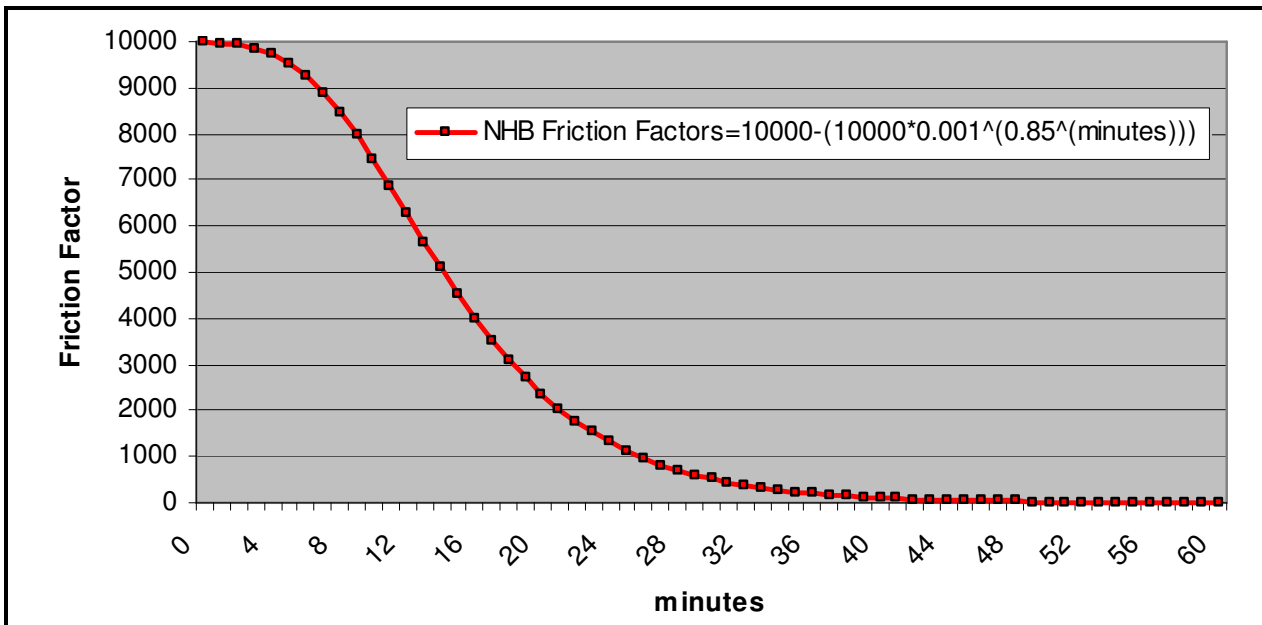


Figure 4.2.3
Non-Home Based – Friction Factors





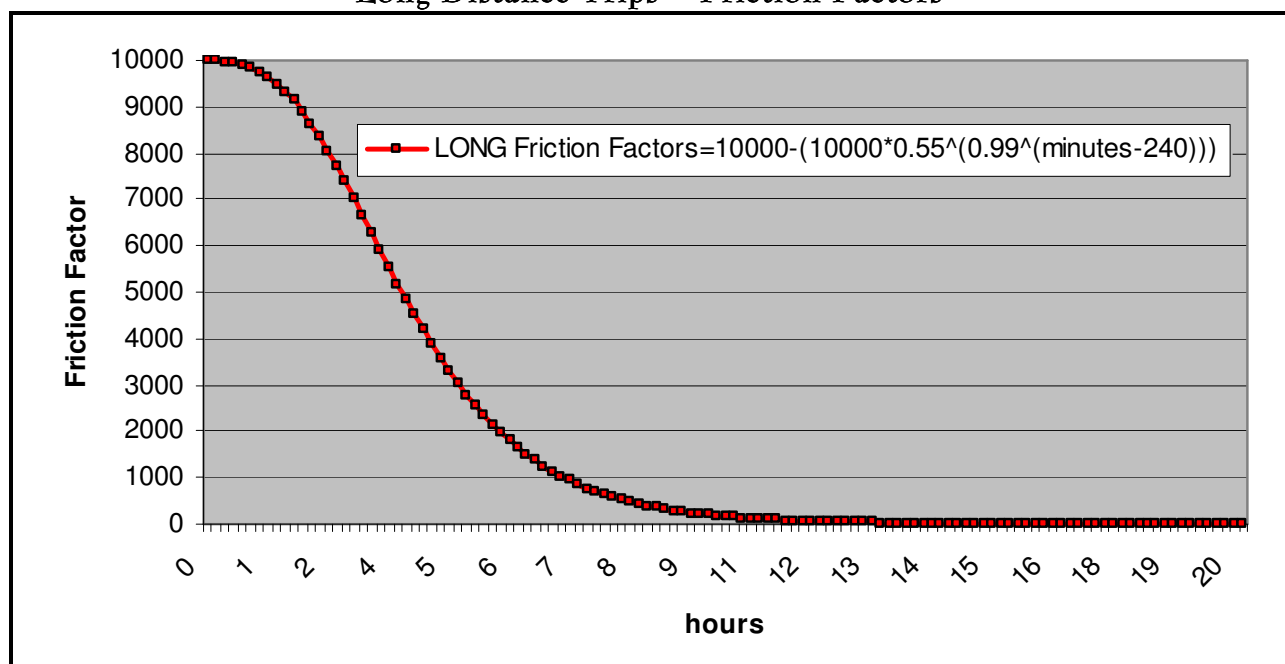
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Properly representing long-distance trips is a significant challenge for large-scale models. To develop a gravity model for the long-distance trip purpose, a reasonable estimate of the trip length frequency distribution of long-distance trips is necessary. NHTS 2001 reports summarize long-distance trips between US Census regions, but this geographic scale is too coarse to estimate a long-distance trip length frequency distribution. The American Travel Survey (ATS) 1995 provided a state-to-state person trip table. Although this is still a coarse geographic scale, it provides a more reasonable basis for developing the trip length frequency distribution. By developing a national level highway network with state centroids it was possible to estimate state-to-state distances, which then made it possible to produce a long-distance trip length frequency distribution. A long-distance friction factor curve, shown in Figure 4.2.4, was then calibrated to closely match the ATS estimated trip length frequency distribution. Figure 4.2.5 displays a comparison of trip length frequency distributions for the ATS 1995 state-to-state trips and the SWGIS long distance trips.

Figure 4.2.4
Long Distance Trips – Friction Factors



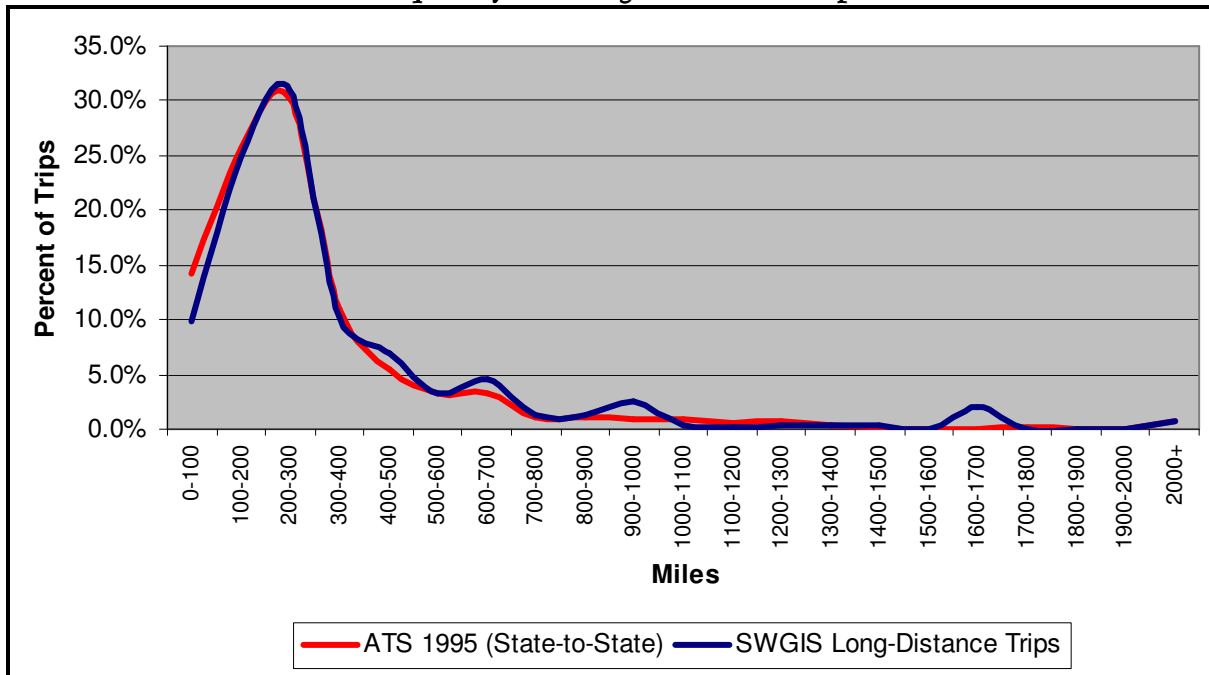


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Figure 4.2.5
Frequency of Long-Distance Trips



4.4. Mode Choice

Since most trips are made by personal vehicles within the study area, mode choice is not required, instead short-distance person trips were simply converted to vehicle trips by applying auto occupancy factors. The following auto occupancy factors were used:

- Home Based Work: 1.14 persons per vehicle
- Home Based Other: 1.80 persons per vehicle
- Non-Home Based: 1.50 persons per vehicle
- Long Distance Trips: 1.63 persons per vehicle

Air travel represents a significant share of long-distance trips, particularly as the distance of trips increase. As a result, the personal vehicle mode share declines with increasing distance. NHTS 2001 personal vehicle mode shares⁷ by distance were applied to convert the total long-distance

⁷ America On the Go, Findings from the National Household Travel Survey, May 2006, Table 4



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person trips to long-distance person trips by personal vehicle. NHTS 2001 shares for long-distance person trips by personal vehicle shares were as follows:

- Trip distance less than 500 miles = 95.4%
- Trip distance between 500 and 750 miles = 61.8%
- Trip distance between 750 and 1000 miles = 42.3%
- Trip distance between 1000 and 1500 miles = 31.5%
- Trip distance 1500 miles or greater = 14.8%

The trip generation, trip distribution and mode choice steps were performed using daily trips formatted in the production to attraction direction. That is, the home-based trips were always defined as going from the home end of the trip (production) to the non-home end of the trip (attraction). For highway assignments, daily trips were converted to origin-destination format, so they were oriented in the true direction of travel.

4.5. Trip Assignment

The highway assignment procedures use a volume averaging loading technique to assign vehicle trips throughout the transportation network. Ten assignment iterations are completed and the final loaded volumes represent of average of the iteration loadings. Since traffic counts for the TTE process were reported as total vehicles with selected locations having truck counts, trips by purpose were combined before assignment. HBW, HBO, NHB and long-distance trips were combined to create a passenger car trip table. Short-distance truck trips and FAF based truck trips were combined to create a single truck trip table. Passenger cars and trucks were loaded separately so that assigned volumes by link could be determined for each vehicle type.

Passenger cars and trucks were assigned using generalized cost paths that account for trip distance in addition to travel time. The following generalized costs were used:

- *Passenger car generalized cost = travel time + 0.5 * distance * auto operating cost / value-of-time*
- *Truck generalized cost = travel time + 1.0 * distance * auto operating cost / value-of-time*

The auto operating cost was assumed to be \$0.15 per mile and the value-of-time was assumed to be \$30 per hour.

Congested travel times are estimated using a modified BPR curve, such that:



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$$\text{Congested Time} = \text{Free-Flow time} * (1 + 0.84 * (\text{Volume/Capacity})^{5.5})$$

In testing 2040 assignments, extreme delays in the Atlanta area in particular caused unreasonable path diversions throughout the Southeast. To minimize this problem, 2040 assignments use a different BPR curve when the Volume-Capacity ratio exceeds 1.0 that replaces the exponent coefficient of 5.5 with 2.0. The BPR curves remains the same if the V/C ratio is 1.0 or less.

4.6. Seed Trip Table Validation

Prior to beginning the TTE process, a few basic validation checks on the reasonableness of the seed trip tables were made. An initial check examined the percent deviation of modeled volumes compared to observed traffic counts. National Cooperative Highway Research Program (NCHRP) Report 255 introduced a Maximum Desirable Deviation curve to determine if modeled volumes were within acceptable deviation bounds. Figure 4.6.1 displays a thematic map of the deviation of modeled volumes compared to traffic counts relative to the Maximum Desirable Deviation.

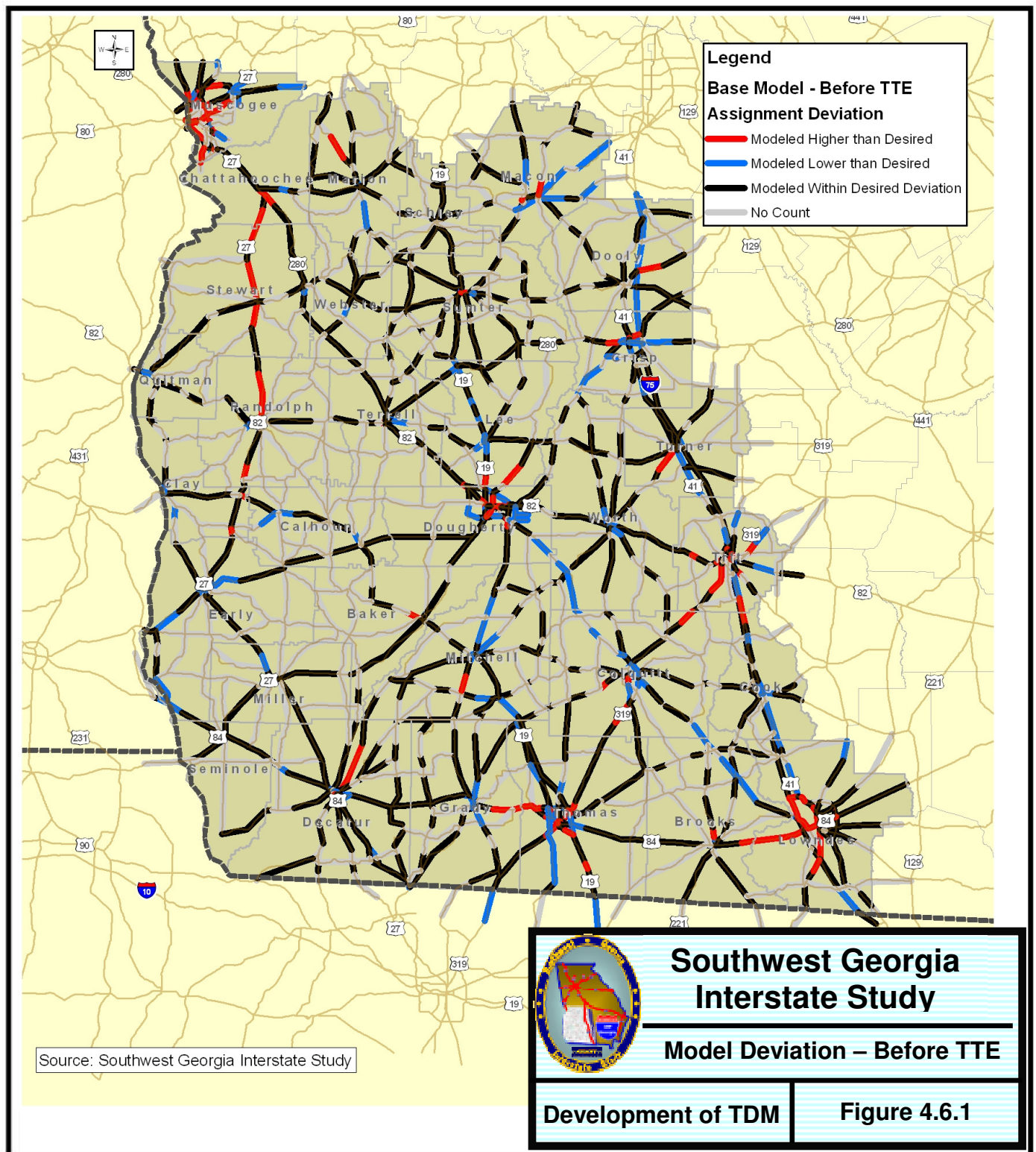
In Figure 4.6.1, black links represent locations where the modeled volumes were within the desired deviation. Red links represent locations where the modeled volumes were high and outside the desired deviation. Blue links represent locations where the modeled volumes were low and outside the desired deviation. Although there were more locations where the modeled volumes were outside the desired deviation limits than would be acceptable alone, there were a substantial enough locations being modeled well to conclude that the seed trip table was reasonable enough for input to trip table estimation.



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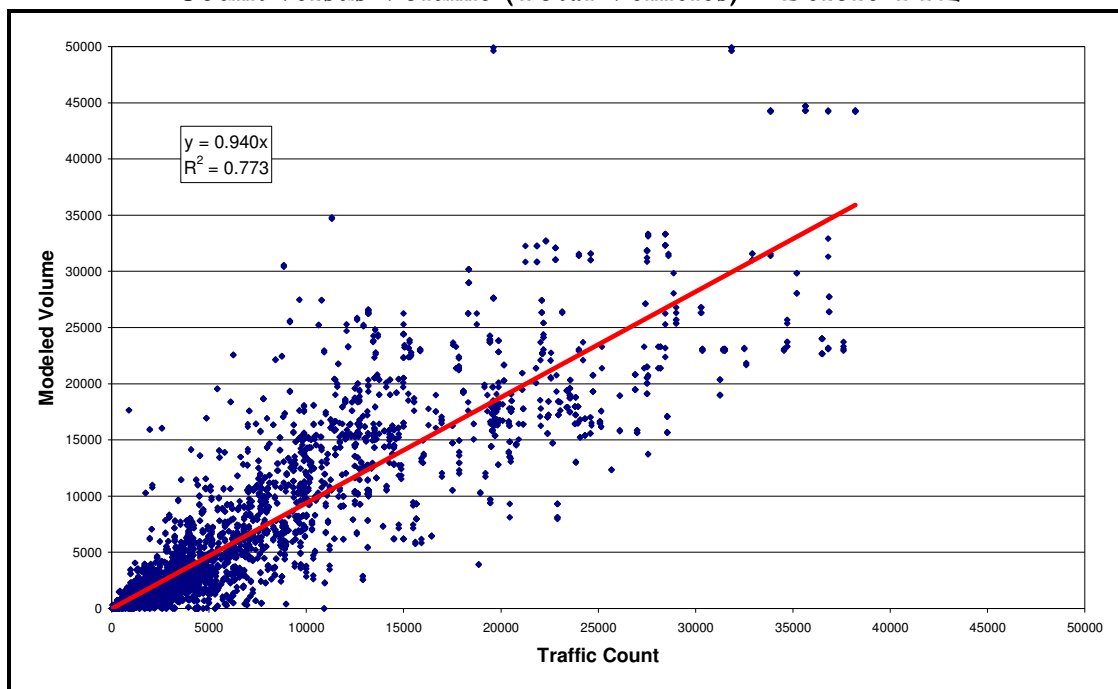
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Scatter plots comparing traffic counts and modeled volumes were also used to evaluate the validity of seed trip tables. Figure 4.6.2 displays a scatter plot of the total modeled volume compared to traffic counts. With an R^2 value of 0.773, the base model without TTE could not be used for future forecasting. However, since the seed trip table assignments produced a relatively strong correlation, the overall seed trip tables offered a reasonable estimate of travel patterns in the study area for input to trip table estimation.

Figure 4.6.2
Count versus Volume (Total Vehicles) – Before TTE



Developing accurate trip tables for commercial vehicle and truck trips is a difficult task because freight movement is a highly complex matter. Complex logistical decisions make it difficult to develop simple procedures that produce accurate results. This difficulty is demonstrated in the scatter plot shown in Figure 4.6.3 which compares truck modeled volumes and counts within the study area. The low correlation shows that the base model without TTE could not be used for forecasting truck volumes. This placed an increased weight on TTE to produce reasonable truck flows, but this was not an unusual result given the complexity of freight logistics.

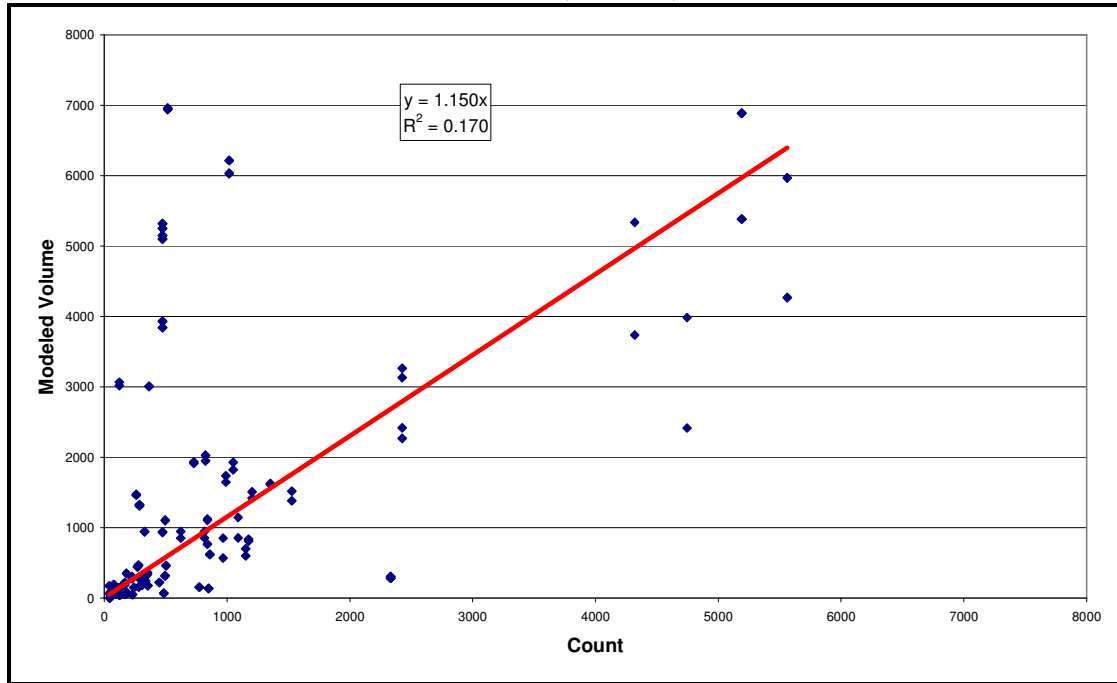


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Figure 4.6.3
Count versus Volume (Trucks) – Before TTE



Vehicle Miles Traveled (VMT) comparisons were also used to validate the seed trip tables. VMT estimates developed from Georgia DOT road characteristics data were compared to VMT resulting from seed trip table assignments. Table 4.6.1 displays a comparison between GDOT VMT and modeled VMT. The comparison shows that the modeled VMT was generally low, but in the correct order of magnitude – indicating that the seed trip table was reasonable for input to TTE.

Table 4.6.1
Vehicle Miles Travel Comparison – Before TTE

Vehicle Miles Traveled (VMT) - SWGIS Study Area				
Area	Functional Class	GDOT RC File (Excluding MPOs)	2006 Base Before TTE	% Difference
Rural	Rural Interstate	3,159,243	2,887,225	-9%
	Rural Principle Arterials	3,154,893	3,265,689	4%
	Rural Minor Arterial	2,306,807	1,777,156	-23%
	Rural Major Collector	1,936,279	1,023,126	-47%
	Total	10,557,222	8,953,197	-15%
Urban	Urban Interstate	726,001	486,162	-33%
	Urban Freeway/Expressway	66,775	33,504	-50%
	Urban Principal Arterial	1,754,286	1,255,812	-28%
	Urban Minor Arterial	911,093	291,769	-68%
	Urban Collector	290,424	2,374	-99%
	Total	3,748,578	2,069,621	-45%
	Grand Total	14,305,800	11,022,818	-23%



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5.0 Trip Table Estimation

Due to the many variables involved, estimated traffic volumes from travel demand models will inevitably differ from observed traffic counts. As a result, it is usually necessary to post-process modeled volumes for use in traffic studies. National Cooperative Highway Research Program (NCHRP) Report 255 outlines a widely used methodology for post-processing model results, but like many approaches to refining travel demand models, the procedures are intended for specific projects or corridors and are not easily applied to an entire region.

PBS&J uses TTE techniques to post-process travel demand model volumes for an entire region. This regional level post-processing is done by developing a trip table that when assigned produces traffic assignments that closely replicate observed traffic counts, while also maintaining reasonable relationships to expected travel characteristics such as trip ends by zone and trip length frequency distribution.

Figure 5.1 outlines the PBS&J TTE process, which was used for the SWGIS model. The TTE process uses the travel demand model trip table as seed matrices. The process then attempts to closely replicate observed traffic counts, while also controlling the trip ends and trip lengths implied in the seed matrix. This is accomplished by first using a basic TTE process that places no controls on trip ends or trip length frequency to create count factored trip tables that when assigned closely match traffic counts. The output of the basic TTE process, count factored trip tables, serves as seed matrices for a tri-proportional⁸ fitting process. The tri-proportional fitting process creates trip tables that closely match trip ends and trip lengths, but may no longer match traffic counts to the desired level. After the tri-proportional fitting process completes, estimated trip tables are created by taking a weighted average of the count factored trip tables and the tri-proportional fitted trip tables. These averaged trip tables attempt to account for all of the desired targets: matching up to traffic counts, trip ends and trip length frequency, but repeated application of the process is usually necessary for all targets to be sufficiently met. The resulting averaged trip tables then serve as seed matrices for the next loop through the process or as the final estimated trip tables if the estimation process is complete.

To determine when the TTE process is complete the output averaged trip tables are assigned to the highway network and the assignment results are compared to the previous loop's results. If the assignment Root Mean Squared Error (RMSE) changes very little between loops, the estimation process completes and the average trip tables become the final estimated trip tables. Depending on

⁸ Tri-proportional fitting is a special case of iterative proportional fitting to three values. In this case, the three values are trip table row totals, column totals, and a target trip-length frequency distribution.



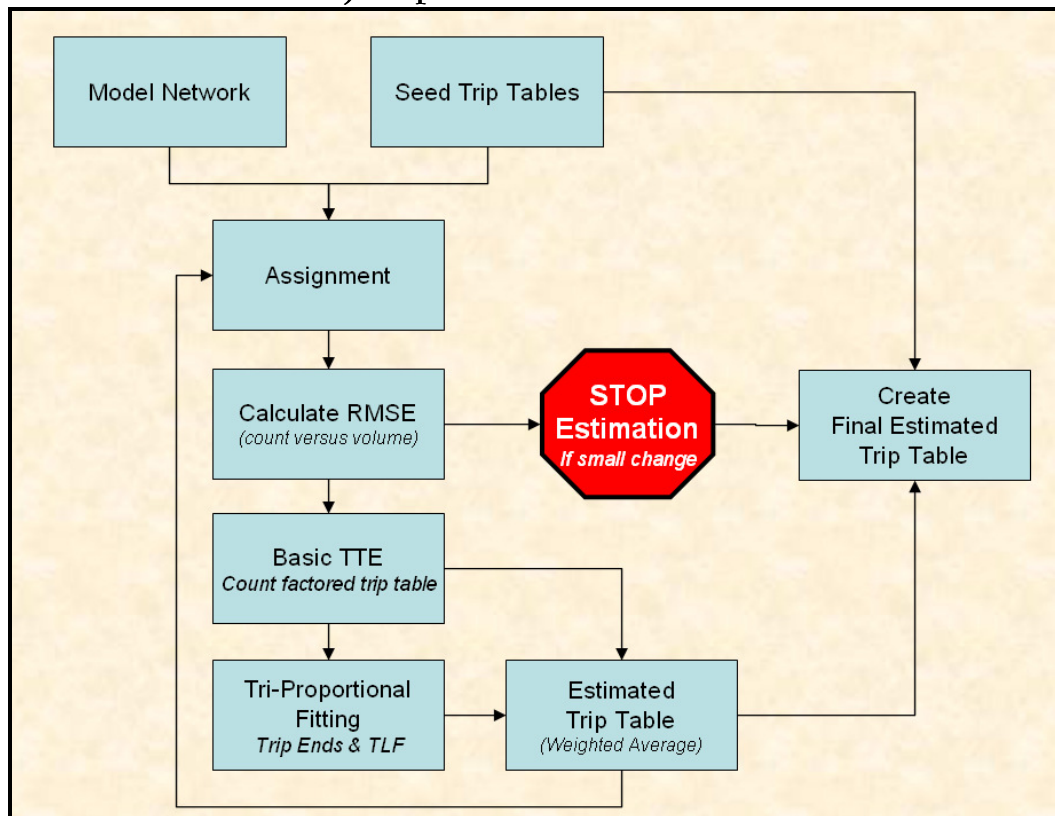
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the application, sometimes seed trip tables from the original model are used in conjunction with the final estimated trip tables to create trip tables that are used for forecasting.

Figure 5.1
PBS&J Trip Table Estimation Process



5.1. TTE Validation

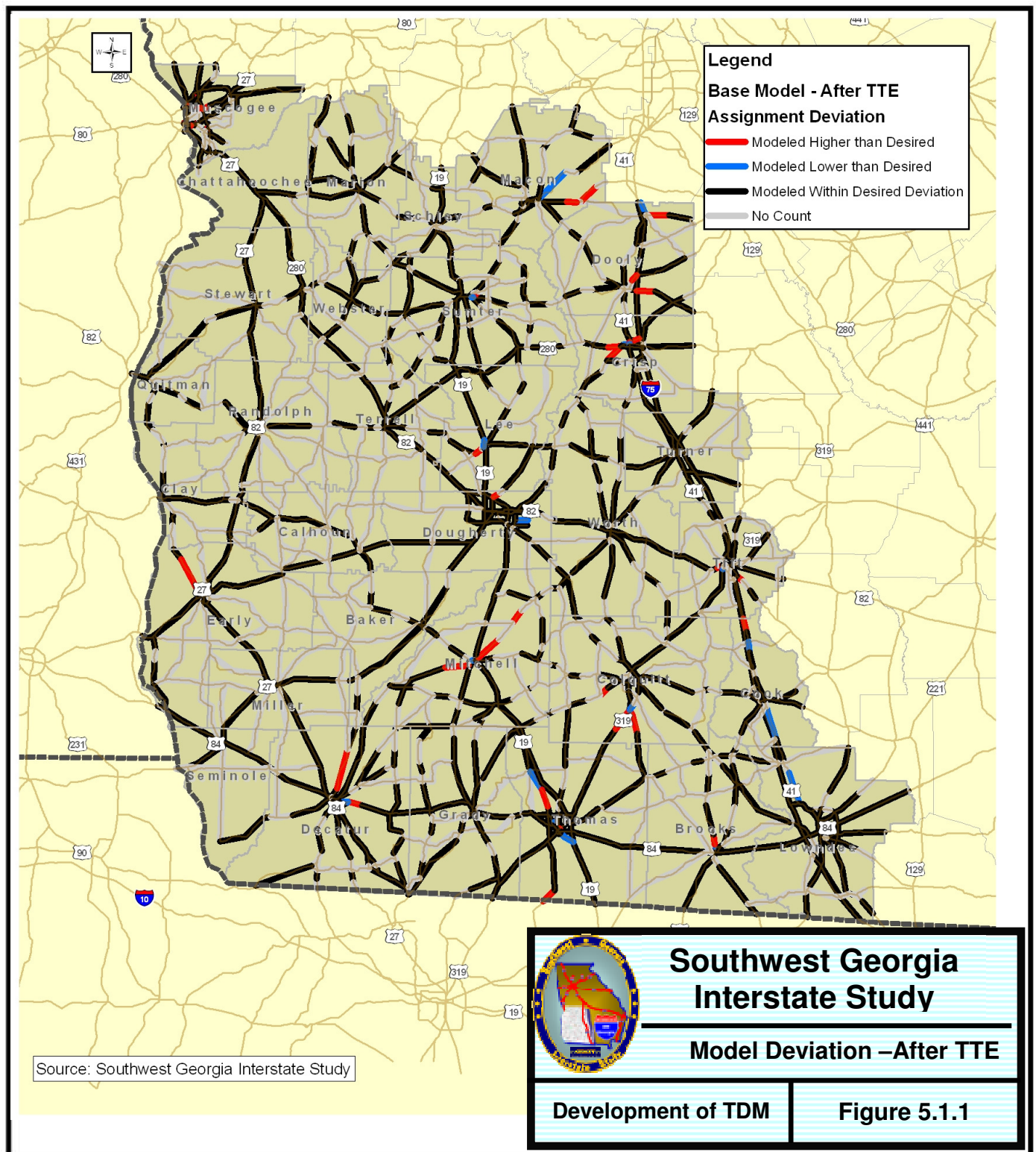
Many of the same validation checks that were made for the seed trip table development were done for the results of the TTE process. Figure 5.1.1 displays a thematic map of the deviation of modeled volumes compared to traffic counts relative to the Maximum Desirable Deviation. This map shows that when the estimated trip tables were assigned, it produces volumes that were much more consistent with observed traffic counts than the seed trip tables produced.



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Figure 5.1.2 displays a scatter plot of the total modeled volume compared to traffic counts. The R^2 value of 0.969 was a considerable improvement over the seed trip tables which had an R^2 of 0.773.

Figure 5.1.2
Count versus Volume (Total Vehicles) – After TTE

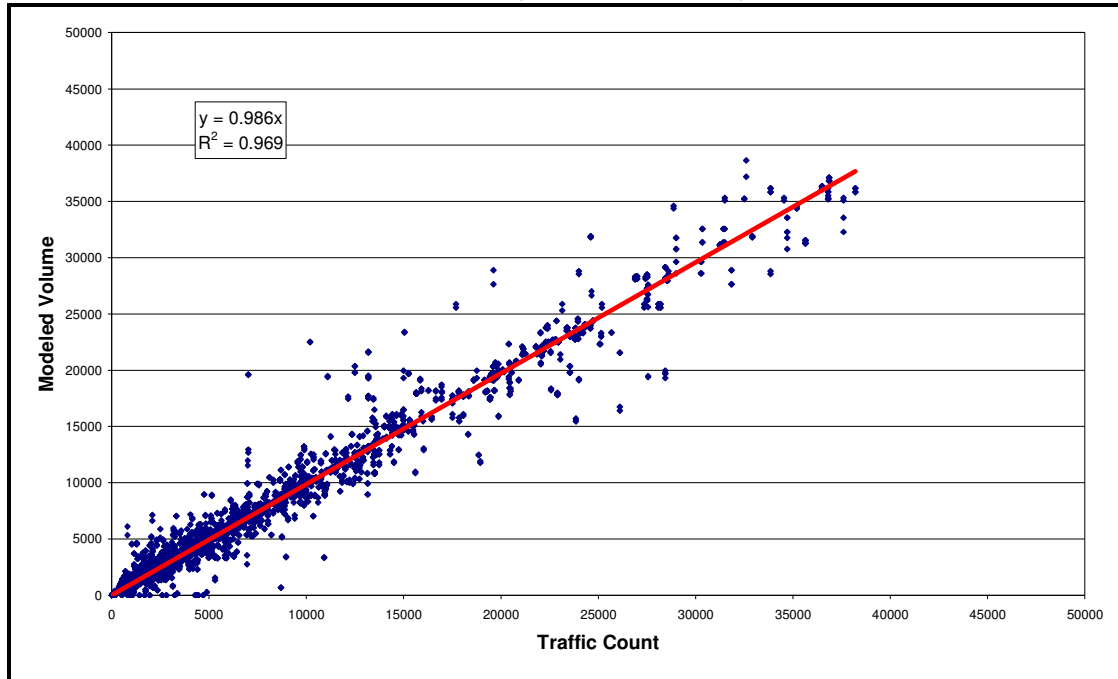


Figure 5.1.3 displays a scatter plot of the modeled truck volumes compared to truck traffic counts. The plot shows a dramatic improvement over the seed trip tables.

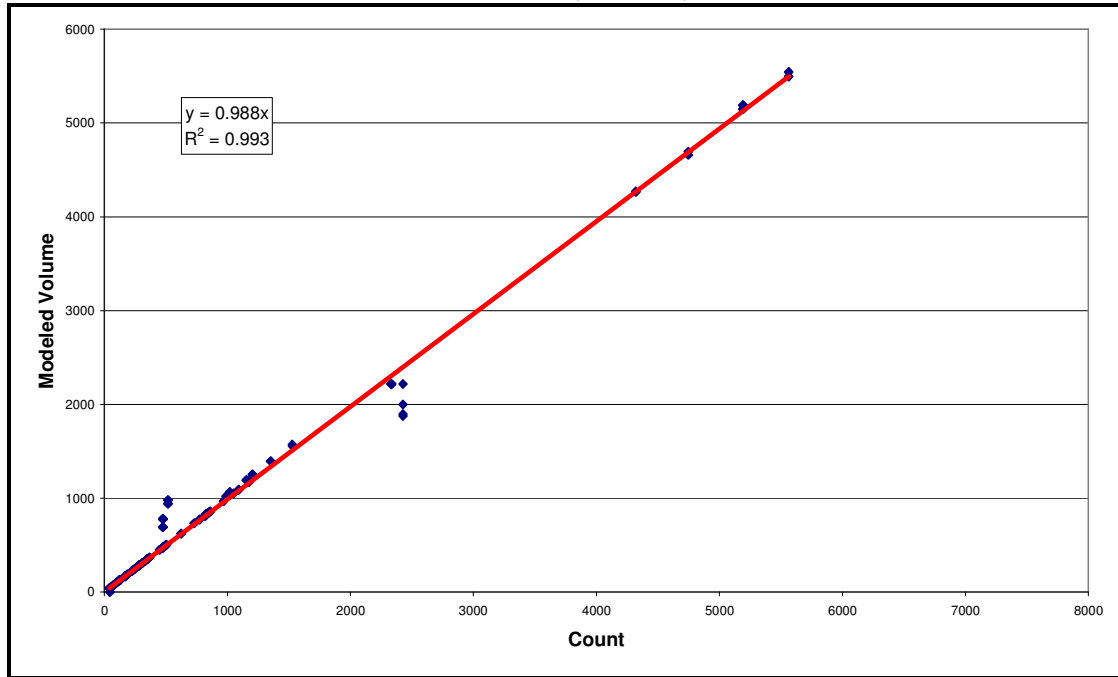


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Figure 5.1.3
Count versus Volume (Trucks) – After TTE



VMT comparisons after TTE, shown in Table 5.1.1, show a significant improvement over the seed trip table results, with the overall study area VMT improving from a 23% difference to a 1% difference.

Table 5.1.1
Vehicle Miles Travel Comparison – After TTE

Vehicle Miles Traveled (VMT) - SWGIS Study Area			
Functional Class	GDOT RC File (Excluding MPOs)	2006 Base After TTE	% Difference
Rural Interstate	3,159,243	3,405,309	8%
Rural Principle Arterials	3,154,893	3,382,497	7%
Rural Minor Arterial	2,306,807	2,611,570	13%
Rural Major Collector	1,936,279	2,429,398	25%
Total	10,557,222	11,828,774	12%
Urban Interstate	726,001	590,752	-19%
Urban Freeway/Expressway	66,775	59,335	-11%
Urban Principal Arterial	1,754,286	1,489,933	-15%
Urban Minor Arterial	911,093	411,452	-55%
Urban Collector	290,424	3,390	-99%
Total	3,748,578	2,554,863	-32%
Grand Total	14,305,800	14,383,637	1%



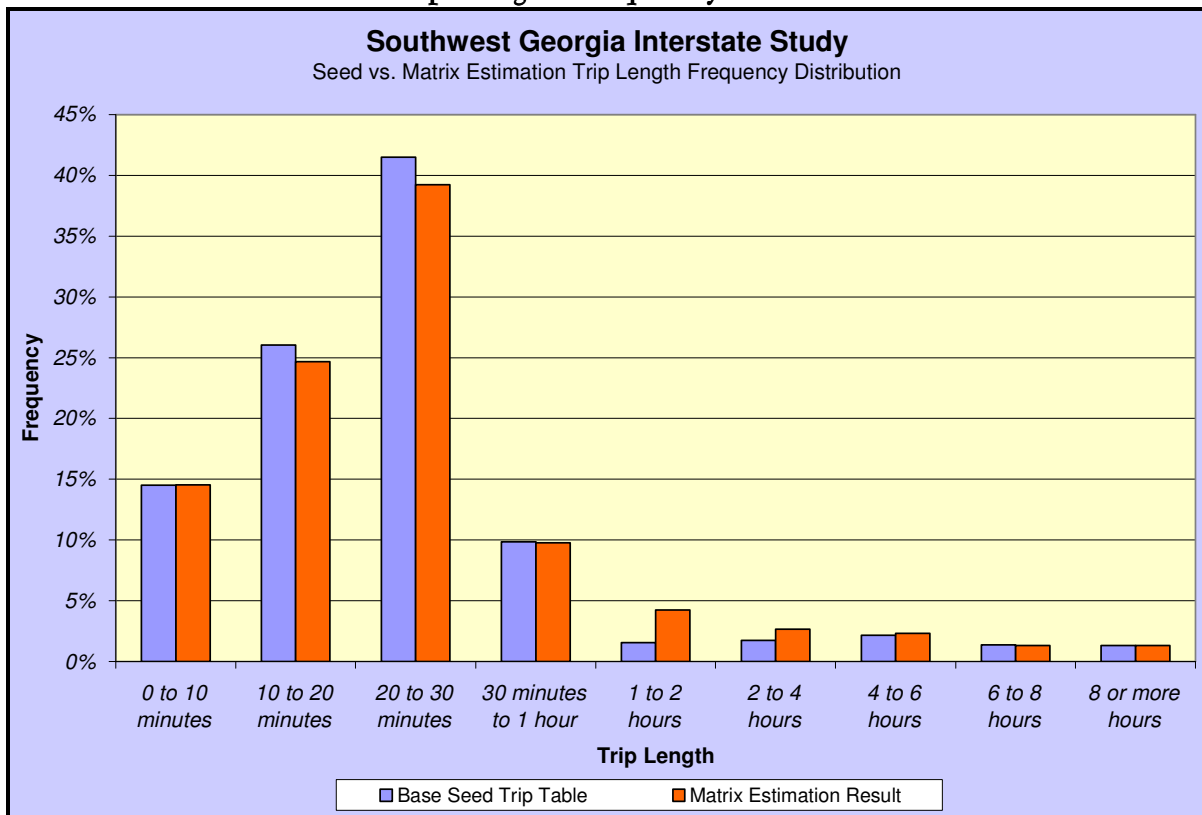
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Since TTE procedures have a tendency to find solutions by adding short trips, it is important to review how the TTE process revised the overall trip length frequency distribution. Figure 5.1.4 displays a chart comparing the trip length frequency distribution for the seed trip tables and the estimated trip tables. The chart shows that the trip length controls applied in the TTE process have kept the trip length frequency distribution reasonably close to the expected distribution. Instead of adding short trips to solve the problem, the TTE process resulted in modest shifts from shorter to longer trips.

Figure 5.1.4
TTE Trip Length Frequency Distribution



The Root Mean Squared Error (RMSE) is commonly used to measure the overall accuracy of modeled volumes relative to counts. RMSE is used because it provides the ability to measure the overall percent difference, when differences may be positive or negative. It is generally not appropriate to use a simple percent difference measure when dealing with positive and negative differences since the overall error is masked due to cancelling effect of the positive and negative values. Table 5.1.2 shows a comparison of percent RMSE by functional class and by volume group



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for the SWGIS model. When compared to reasonable %RMSE targets, the SWGIS is well within expected accuracies.

Table 5.1.2
Assignment %RMSE Summary

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<i>RMSE Summary - Modeled Volume versus Counts</i>		
FACILITY TYPES	%RMSE	TARGET
ALL FACILITY TYPES	19%	<30%
FREEWAYS & EXPRESSWAYS	10%	<30%
PRINCIPAL ARTERIALS	22%	<30%
MINOR ARTERIALS	43%	<50%
COLLECTORS	40%	<75%
VOLUME GROUP	%RMSE	TARGET
ALL VOLUME GROUPS	19%	<30%
DIR COUNT = 0 - 1000	59%	<100%
DIR COUNT = 1001 - 2500	43%	<75%
DIR COUNT = 2501 - 5000	26%	<75%
DIR COUNT = 5001 - 10000	18%	<50%
DIR COUNT > 10000	12%	<30%

Screenlines are imaginary lines that split the modeled area into two sides that are used to capture all traffic moving across the screenline using highway segments along the line. Strategically placed screenlines can help to gauge the accuracy of the overall distribution of trips and can also help to identify corridors and highway facilities that are not being modeled effectively. Figure 5.1.5 displays the major screenlines that were used in the model validation. Table 5.1.3 displays a summary of the screenline comparisons, which indicates that the model assignments are well within the screenline targets. Screenline targets are based on a maximum desirable deviation curves included in NCHRP Report 255.

Table 5.1.3
Screenline Comparisons

Screenline		Total Modeled	Total Traffic	Target Value	Model Difference
Number	Location	Volume	Counts		
1	Flint River	159,398	165,710	+/- 20.5%	-3.8%
2	North	91,571	90,550	+/- 25.8%	1.1%
3	South	164,113	177,990	+/- 19.9%	-7.8%
Total - All Screenlines		415,082	434,250	+/- 14.2%	-4.4%
Total - All Count Locations*		33,287,536	33,335,751	+/- 2.71%	-0.1%

* All count locations includes study area and tract level links



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